A stated choice experiment on electric vehicle adoption in Finland

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Tiivistelmä – Referat – Abstract

One-fifth of Finland's total greenhouse gas emissions and two-fifths of the Effort Sharing sector's emissions come from domestic transportation. Of the domestic transportation emissions, 94% comes from road traffic. The target for Finland is to reduce 39% of the greenhouse gas emissions from the Effort Sharing sector by 2030, and Finland is committed to halving its emissions from traffic by the year 2030 compared to the 2005 level. The electrification of the vehicle fleet is one of the instruments set to achieve the emission reduction targets of the transportation sector. An ambitious goal of 700 000 electric vehicles, of which a significant part is battery electric vehicles, is suggested for 2030.

The study explores the most significant attributes and the factors that affect the likelihood of adopting electric vehicles in Finland. The choice experiment data was collected by a survey questionnaire. The data comprises 409 respondents and represents the Finnish driving license holders well regarding age, gender, and living county. The data was analysed with econometric models using Nlogit and SPSS software.

The results show that the most important attributes in vehicle purchase choice are purchase price, driving range, and charging time. Driving costs and CO_2 emissions from driving were not statistically significant in this study. Plug-in hybrids were chosen more frequently than battery electric vehicles. The study finds many socio-demographic characteristics, and vehicle and driving-related factors that affect vehicle purchase choice. These simultaneously statistically significant characteristics for the vehicle purchase choice for battery electric vehicle are living county Uusimaa, university degree, gender woman, age less than 50 years, and driving less than 50 km per day. The variables found to increase the probability to choose a plug-in hybrid vehicle are residence in Northern or Eastern Finland, university degree, gender woman, row or semi-detached house, and the possibility to charge an electric vehicle at home. The study identifies the respondents who never chose an electric vehicle in the choice tasks and reveals a wide set of attitudes towards electric vehicles. The study reveals respondents' overall lack of information on electric vehicle and traffic emissions, and instruments for emission reductions.

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electric vehicle, battery electric vehicle, plug-in hybrid vehicle, choice experiment, Finland

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Tiivistelmä – Referat – Abstract

Yksi viidesosa Suomen kokonaispäästöistä ja kaksi viidesosaa taakanjakosektorin kasvihuonekaasupäästöistä tulee kotimaisesta liikenteestä. Tieliikenteen osuus liikenteen päästöistä on 94 %. Suomen tavoitteena on vähentää 39 % taakanjakosektorin päästöistä ja 50 % liikenteen päästöistä vuoteen 2030 mennessä, verrattuna vuoden 2005 tasoon. Liikenteen sähköistyminen on asetettu yhdeksi keinoista päästövähennystavoitteiden saavuttamiseksi. Vuodelle 2030 on ehdotettu kunnianhimoista 700 000 sähköauton tavoitetta, josta merkittävä osa olisi täyssähköautoja.

Tämä tutkielma kartoittaa auton hankintapäätökseen vaikuttavia tekijöitä. Tutkimus on toteutettu valintakoemenetelmällä ja aineisto on kerätty kyselytutkimuksella. Aineisto koostuu 409 vastaajasta ja aineisto kuvastaa hyvin Suomen täysi-ikäisiä ajokortinomistajia niin iän, sukupuolen kuin asuinkunnankin mukaan. Aineisto on analysoitu ekonometristen mallien avulla käyttäen Nlogit ja SPSS ohjelmistoja.

Tutkimuksen tulokset osoittavat, että tärkeimmät auton ostopäätökseen vaikuttavat tekijät ovat hinta, ajoetäisyys ja latausaika. Ajokustannukset ja ajonaikaiset CO_2-päästöt eivät olleet tilastollisesti merkitseviä tekijöitä. Ladattavia hybridejä valittiin todennäköisemmin kuin täyssähköautoja. Samanaikaisesti merkitsevät tekijät, jotka vaikuttavat positiivisesti sähköauton valintaan ovat täyssähköautolle asuinkunta Uusimaa, korkeakoulututkinto, sukupuoli nainen, ikä vähemmän kuin 50 sekä päivittäiset ajokilometrit alle 50 km. Ladattavan hybridin valintaan positiivisesti vaikuttavat asuminen Pohjois- tai Itä-Suomessa, korkeakoulututkinto, sukupuoli nainen, asuminen rivi- tai paritalossa sekä mahdollisuus ladata sähköautoa kotona. Tämä tutkielma identifioi vastaajat, jotka eivät koskaan valinneet sähköautoa valintatilanteessa ja paljastaa laajan kirjon asenteita sähköautoilua kohtaan. Tulosten mukaan vastaajilla on puutteelliset tiedot koskien sähköautojen ja liikenteen päästöjä sekä päästövähennysinstrumentteja.

Avainsanat – Nyckelord – Keywords

sähköauto, täyssähköauto, plug-in hybridi, ladattava hybridi, valintakoemenetelmä, Suomi

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Contents

Abbreviation	Explanation
EV	Electric vehicle. Includes all vehicles with a rechargeable electric battery, such as battery electric vehicle and plug-in hybrid vehicle
BEV	Battery electric vehicle. A vehicle with one power source: a rechargeable electric battery
PHEV	Plug-in hybrid electric vehicle. A vehicle with two power sources: a rechargeable electric battery and an internal combustion engine
CV	Conventional vehicle. A vehicle with one power source: an internal combustion engine

1 Introduction

1.1 Emissions and emission reduction targets in Finland

The Climate Act (609/2015), which entered into force in June 2015, laid the foundation for long-term and cost-effective planning and monitoring of climate policy in Finland. The Climate Act aims to nationally reduce anthropogenic greenhouse gas emissions as well as mitigate and adapt to climate change. The Climate Act is a targeted framework law for government authorities that do not include substantive legislation covering different sectors. The Climate Act sets a long-term greenhouse gas emission reduction target of at least 80% by 2050 compared to 1990 levels. (Ministry of Economic Affairs and Employment of Finland, 2017)

European Union (EU) divides greenhouse gas (GHG) emissions into EU Emission Trade Sector (EU ETS), Effort Sharing sector, Land use and land use change and forestry (LULUCF), and international aviation and marine traffic. The EU Effort Sharing sector comprises transport, agriculture, buildings, waste management, industrial processes and products use, and energy. The largest emitters of the Effort Sharing sector in the EU are traffic, buildings, and agriculture. In Finland, the largest emitters of Effort Sharing sector are traffic, agriculture, buildings, and industry. (European commission 2019) The Effort Sharing legislation determines binding annual greenhouse gas emission targets for the member states for 2021-2030. (European commission 2019)

Domestic emissions from traffic comprise road traffic, diesel powered railway traffic, and domestic waterborne transport. Electricity powered railway, water, and road traffic are counted as part of electricity production emissions in EU ETS. Emissions from domestic aviation are treated as independent emission source. (IPCC 2014) In 2019 the domestic traffic GHG emissions were approximately 11.1 million tons CO_2 equivalent (Statistics Finland 2019), which is one-fifth of Finland's total greenhouse gas emissions and 40% of the Effort Sharing sector's emissions (Ministry of Economic Affairs and Employment 2017). Road traffic emissions cover approximately 94% of national traffic emissions. In 2019, the greenhouse gas emissions from road traffic were around 10.54 million tonnes, of which 54% were from private passenger vehicles, 41% from vans and trucks, and the rest from e.g. buses and motorcycles (Lipasto 2019). In addition to road traffic, the traffic's emissions comprise railroad traffic 1%, aviation 2%, and maritime 4%. (Lipasto 2019)

According to EU Effort Sharing legislation, Finland needs to reduce 39% of the greenhouse gas emissions from the Effort Sharing sector by the year 2030 (European Commission 2020). Finnish Government is committed to halve its emissions from traffic by the year 2030 compared to the 2005 level. (Energy and climate strategy 2016, Government Programme 2019). The emissions from domestic traffic were 12.7 million tonnes in 2005. (Lipasto 2019) A mid-term goal in the current Government Programme for Finland is to be carbon neutral in 2035 (Government Programme 2019). Emission reductions from transportation need to meet this target, which means that all emissions from the transportation sector need to be removed before 2045. (Ministry of Transport and Communications 2020)

The actions that will enable Finland to achieve the targets for 2030 in the Government Programme are outlined in the National Energy and Climate Strategy. The National Energy and Climate Strategy systematically sets the course to achieve 80-95% greenhouse gas emission reduction targets by 2050. The Strategy is currently being revised to meet the targets. Finland will phase out the use of coal for energy, the share of transport biofuels will be increased to 30%, and blending 10% of bio liquids to light fuel oil used in machinery and heating will become obligatory. The minimum aim for road traffic is 250 000 electric and 50 000 gas powered vehicles in 2030. (Ministry of Economic Affairs and Employment of Finland 2017) Ministry of Transport and Communications suggests the goal to be 700 000 electric vehicles, of which a significant part is battery electric vehicles, in 2030 (Road map for fossil-free transport 2020). Developments to the electricity market will be made at regional and European level. Electricity’s demand and supply flexibility will be increased, and system-level energy efficiency improved. The end consumption share of renewable energy will increase to approximately 50% and the energy’s self-sufficiency to 55%. The use of imported oil will be halved. (Ministry of Economic Affairs and Employment of Finland 2017) In the Effort Sharing sector, traffic has the highest potential to reduce emissions, and that is where actions are specifically addressed. The aim is to make the whole transport system very low emission in a long timeframe. (Ministry of Economic Affairs and Employment of Finland 2017)

1.2 Electric vehicles in Finland

In 2019, there were approximately 3 160 000 vehicles in Finland, of which 2 720 000 were passenger vehicles. Passenger vehicles comprise 70% gasoline vehicles, 28% diesel vehicles, 0.91% plug-in hybrid vehicles (PHEV), 0.17% battery electric vehicles (BEV), and 0.34% gas vehicles. At the end of 2020, there were 9697 (0.35%) battery electric vehicles and 45 621 (1.66%) plug-in hybrid vehicles in Finland. The number of electric vehicles (EV) has increased by 88% in a year, from 29 365 to 55 318. The quantity of battery electric vehicles increased by 108% and plug-in hybrid vehicles by 85%. (Statistics Finland 2021a)

From the year 2012 to 2019, the market share of newly registered electric vehicles has risen from 0.11 to 6.89%. The market share of battery electric vehicles increased from 0.05 to 1.66%, and the market share of plug-in hybrid vehicles increased from 0.06 to 5.22%. The electric vehicle market share grew by 163% in 2020. At the end of the year, the market share was 18.13% comprising 4.40% battery electric vehicles and 13.72% plug-in hybrids. (Statistics Finland 2021b)

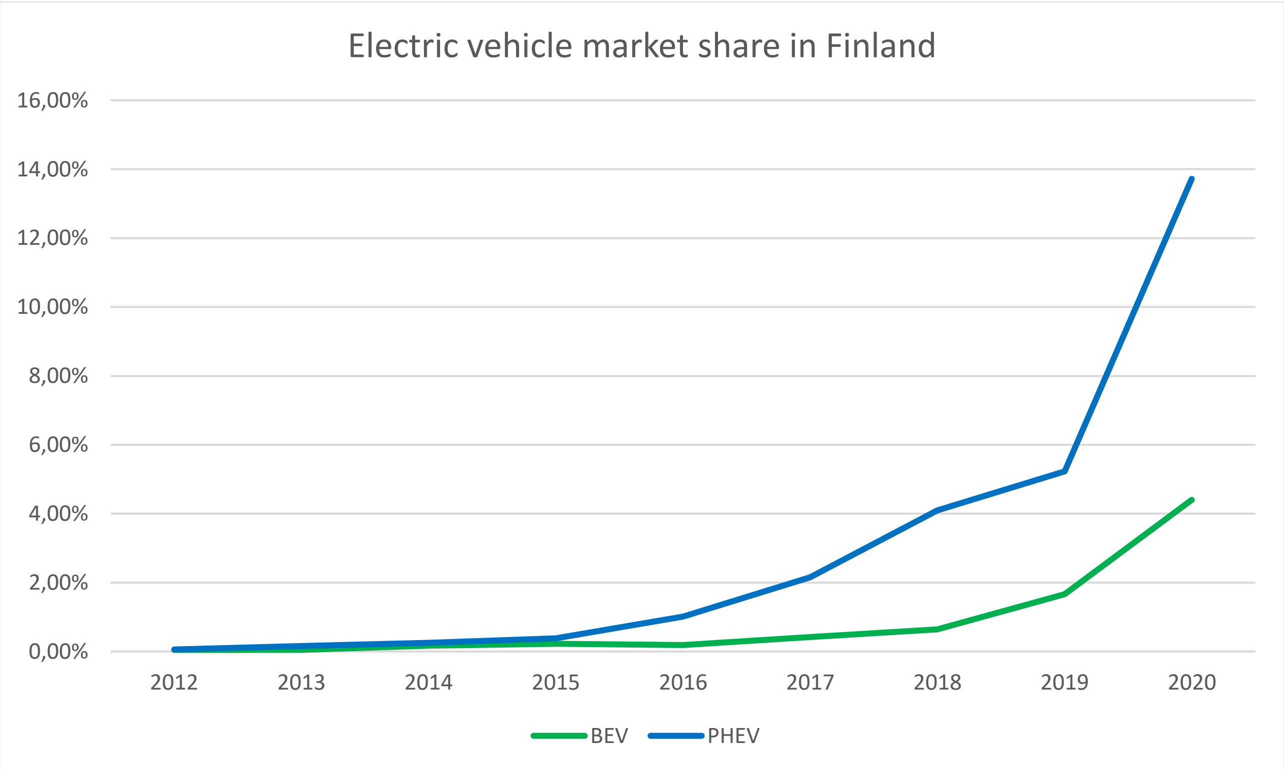

Figure 1. Electric vehicle market share in Finland, 2012 – 2020 (Statistics Finland 2020)

At the end of 2020, there were 1255 public charging stations, of which 274 were fast charging stations. The increase in one year has been 31%. The charging stations comprise 4406 (plus 87 Tesla Destination Chargers) Type 2 charging points and 365 fast charging points (plus 58 Tesla Superchargers). (Technology Finland 2021) The EU Directive 2014/94/EU recommends having one Type 2 charging point for every ten electric vehicles and one fast charging point (CCS, CHAdeMO) for every 100 electric vehicles. Currently, the ratio is 1:12.6 and 1:26.6. Approximately 50% of all charging stations are in the Helsinki metropolitan area, Tampere, and Turku area. (Technology Finland 2021)

Operative policy instruments in Finland affect electric vehicle purchase decisions. A purchase subsidy of 2000€ is available from 2018 to 2021 for new battery electric vehicles costing up to 50 000€. The subsidy also applies to long-term rentals (>3 years). (Traficom 2019) From the beginning of 2018 to the end of 2020, 2828 battery electric vehicles have been registered using this subsidy. (Technology Finland 2021) A taxation value of a company car with 0 g of CO_2 tailpipe emissions is decreased by 170 euros per month in 2021-2025. Thus, some of the battery electric company vehicles are cheaper than corresponding combustion engine vehicles for the user. (EV 198/2020 vp) A scrapping premium is granted for private passenger vehicle owners who scrap their vehicle, which was newly registered before 2011. The premium can be used to purchase a low emission car, an electric bike, a public transportation ticket, or other transportation services. The compensation is emission dependant, its value differs from 1000 to 2000€, and it is in effect from December 2020 to the end of the year 2021. Battery electric vehicles and plug-in hybrid vehicles with CO_2 emissions less than 95 g/km are entitled to a 2000€ premium. The scrapping premium can be combined with the purchase subsidy. (Traficom 2021)

To increase home charging infrastructure, 45% of installation costs (max 90 000€) are covered for communities owning a residential building. A requirement for the installation subsidy is minimum readiness for five charging points. From autumn 2020 onwards, 55% of the installation cost are covered (max 90 000€) if at least half of the charging points deliver 11 kW or higher output. (ARA 2020) This subsidy entered into force in 2018. At the end of 2020, there have been 932 applications for 18 011 charging points. (Technology Finland 2021) In addition to the subsidy, the installation of home charging points entitles tax credit for household expenses. (Finnish Tax Administration 2017) Free electric vehicle charging at the workplace has been treated as a taxable benefit with a monetary value of 30€ per month (Finnish Tax Administration 2019). However, from the beginning of 2021 to the end of 2025, electric vehicle charging at the workplace and public charging stations is tax-free

(EV 198/2020 vp). Since 2018, there has been an investment subsidy for charging infrastructure to foster the deployment of electric and biogas vehicles in transport. This subsidy operates through tendering. In the years 2018 and 2019 combined, 1.4 M€ were granted to contractors, who have invested 4.81 M€ in the charging infrastructure. In October 2020, the third tendering took place, and the investment subsidy is allocated as follows: 3 M€ to natural gas infrastructure, 750 000 € to local public transport charging infrastructure, and 1.75 M€ to electric charging infrastructure with an output higher than 22 kW. (Finnish Energy Authority 2020)

The Programme of Prime Minister Sanna Marin's Government 2019 proposes to renew employee's car benefit so that it significantly favours low-emission vehicles, remove the tax from electric vehicle charging benefits, continue and increase support for EV charging infrastructure construction, establish a minimum number for the EV charging points in major renovations on the property, remove administrative barriers for EV charging point construction especially in housing companies, and set an obligation for service station chains to provide a certain number of electric vehicle charging points at service stations. (Government Programme 2019)

1.3 Literature review

The literature review presents previous literature on the adoption of electric vehicles investigating the important factors for choosing an electric vehicle. For comparability, the focus is on the most recent European studies.

Driving range has been found to be a major barrier for electric vehicle adoption in studies through time and is also identified as one in the most recent ones. The demand for long trips and high range preferences is notable. (Noel et al. 2019, Molin et al. 2019). Although it has been discovered that range preference for battery electric vehicles is typically higher than the consumers' real demand and that the driving range of a battery electric vehicle would meet the majority of consumers' daily driving requirements even in harsh winter conditions (Zarazua de Rubens 2019). The higher range demand is a consequence of being familiar with a conventional vehicle (CV), resulting in the similar expectations towards battery electric vehicle. Interestingly, an experiment proved that three months trial of driving a battery electric vehicle decreased the demand for driving range remarkably. (Franke and Krems 2013) Education about real-life battery performance and driving range could tremendously remove range anxiety (Zarazua de Rubens 2019). Range anxiety refers to a fear of not being able to drive as far as needed with an electric battery (Backstrom 2009). The length of the all-electric driving range had the highest impact on plug-in hybrid vehicle adoption (Li et al. 2019).

Long battery charging time (Noel et al. 2019) and lack of charging infrastructure are regarded as another technical barrier. The possibility of charging at the workplace, and the number and location of charging stations in public areas are significant for possible electric vehicle adoption. (Jensen et al. 2013) On the contrary, consumer demand for public charging stations in supermarkets, parks, and restaurants, has been demonstrated to be small. Consumers prefer to charge electric vehicles at home. (Skippon and Garwood 2011, Plötz et al. 2014.) Regarding charging, in Sweden, 70% of electric vehicle owners stated that they charge their vehicles only at home, 12% stated that they use charging points at their workplace, and only 1% charge while doing errands. About every sixth owner of electric vehicle (15%) pointed out that they charge their vehicles whenever they can. (Vassileva and Campillo 2017).

The high purchase price has been seen as a barrier to adopt electric vehicles in many studies (Zarazua de Rubens 2019, Rahmani and Loureiro 2019, Orlov and Kallbekken 2019). In contrast, the lower operational cost has been in favour of battery electric vehicle adoption (Broadbent et al. 2019). According to Zarazua de Rubens (2019) battery electric vehicle prices should be under 30 000€ to be comparable to conventional vehicles and thus easier to adopt. Purchase tax and purchase price reductions showed a significant positive effect on electric vehicle adoption (Liao 2017).

In addition to the range, charging time, and purchase price, being the most important vehicle attributes considered when choosing an electric vehicle, other technical factors have been identified. These include top speed, battery life, acceleration, fuel cost, driving pleasure, and low noise. (Noel et al. 2018, Jensen et al. 2013, Bühler 2014) When characterizing the profile of potential battery electric vehicle buyers, Zarazua de Rubens (2019) proposed that consumers are not only interested in the environmental aspects of a battery electric vehicle, but also the technological profile of the vehicle. Therefore, the marketing of battery electric vehicles should have more focus on technological factors.

A Swedish study (Egnér and Trosvik 2018) empirically examined the impact of local policy instruments designed to promote electric vehicle adoption. Data from the years 2010 to 2016 revealed that an increased number of public charging points increased the battery electric vehicle adoption rate, particularly in the urban areas. This implies that the increase in charging points decreases the range anxiety and supports the battery electric vehicle adoption for those who cannot charge at home.

Parking incentives had a positive effect on the battery electric vehicle adoption but not as robust as public charging infrastructure improvement. Free parking is a relatively cheap incentive compared to purchase subsidies, especially in municipalities where parking is expensive and limited. In addition, Hardman (2019) found parking incentives as significant promoters in electric vehicle adoption along with toll exceptions.

When comparing consumer preferences for battery lease, vehicle lease, and mobility guarantee, the results showed that for a battery electric vehicle, vehicle leasing is the most popular option. Battery leasing is less preferable than a full-price purchase. Mobility guarantee for up to 14 days per year does not make a battery electric vehicle more appealing, which indicates that it does not play a major role in decision-making compared to the other attributes, such as purchase price, driving range and energy cost, which were the most valued ones. The study suggests that business models for battery electric vehicle leasing should be implemented and subsidized based on these results. For conventional vehicles and plug-in hybrid vehicles, a full-price purchase is preferred to vehicle leasing. (Li et al. 2019)

In a Nordic study, vehicle-to-grid (V2G) capability increased the interest in battery electric vehicle adoption in Norway and Finland. V2G technology enables pushing energy from the battery of an electric car back to the power grid (Virta 2021). Clear policy signals would improve consumer knowledge of the technology, and V2G could be used as a cost-effective way to increase electric vehicle adoption. (Noel et al. 2019) V2G implementation could prevent electric grid overload during evening peak hours and ensure no need to use extra fossil fuels to charge electric cars. (Vassileva & Campillo 2017)

1.4 Aim of the study

As stated earlier, one-fifth of Finland’s total emissions and two-fifths of the Effort Sharing sector emissions come from domestic transportation. The emission reduction targets for transportations are ambitious and addressed particularly to road traffic. The electrification of the vehicle fleet is one of the instruments to achieve the emission reduction targets of the transportation sector, especially targets related to private passenger vehicles. The transition to electric vehicles is proceeding rather slowly, and therefore more information on the factors affecting the electric vehicle purchase choice in Finland is needed.

The study bases on a choice experiment data collected by a survey questionnaire. The data comprises of Finnish driving license holders across the country. The data is analysed with econometric models.

The study aims to explore the most important attributes that affect the adoption of electric vehicles and the factors that affect the likelihood of adopting electric vehicles. The study examines the respondents' current vehicle and driving habits and how these and socio-demographic characteristics affect the vehicle purchase choice. It observes the respondents' attitudes and perceptions of electric vehicles while examining the relationship between the attitudinal variables reflected by the attitudinal statements. The study identifies the reasons for not choosing an electric vehicle in the choice tasks. The study aims to provide information on methods that increase electric vehicle adoption in Finland.

This thesis comprises of six chapters. In chapter two, the choice experiment method and theory behind the analysis are explained. Chapter three presents the survey questionnaire, choice tasks, and data. Chapter four presents the results. In chapter five, the results are discussed and compared to previous studies. Chapter six provides a conclusion.

2 Methods and Theory

2.1 Choice experiment method

Stated preferences methods allow estimating the preferences for new products and policies that do not currently exist, and thus, eliciting the citizen preferences for these policies or products, using a survey questionnaire. When a good or a service is best characterized by its attributes, a choice experiment (CE) method is applicable. (Holmes et al. 2017). The specific choice alternatives are characterized by different levels of the attributes, and a choice task involves selecting from among two or more alternatives that differ in their attribute levels. (Phaneuf & Requate 2017) The choice experiment context reminds the respondent of actual market behaviour as the consumer makes the purchase choice by comparing the attributes of the choice alternatives. (Lancaster 1966)

Choice experiment provides multiple potential advantages compared to other valuation methods. Choice experiments can provide information for changes in a single attribute or values for changes in attribute levels or values for multiple changes in attributes thus resulting a response surface of values rather than a single value. The attributes can be modified in a way that they reflect levels outside the current market environment. Characteristics are typically exogenous and not collinear. Potential advantages bring challenges on the way. Strategic behaviour and hypothetical bias decrease reliability in the choice experiment. Comparing multiple attributes in new choice situations may raise cognitive difficulty. When trade-offs between the alternatives are too complex, behavioural responses, such as the use of decision heuristics, may occur and the answers do not reflect actual market choice. (Holmes et al. 2017)

2.2 Modelling consumer’s choice with a random utility model

The analysis of choice experiment responses is based on an extension of the random utility maximization (RUM) model. The model underlies discrete choice contingent valuation responses and recreation site choices between opposing alternatives. The choice experiment format focuses on the observation of respondents on the trade-offs between attributes that are implicit in making a choice. Model estimates are based on utility variations across the alternatives included in choice sets.

The RUM model is based on the assumption that individuals know their utility with certainty, but the respondent utility is not perfectly observed by the analysts thus the unobservable elements are part of the random error. In the model, the utility is the sum of systematic (v) and random ($\mathcal{E}$) factors for individual k and are expressed as follows:

$$v_{ik} = v_{ik}(Z_i, y_k - p_i) + \mathcal{E}_{ik} \tag{1}$$

where the true but unobservable indirect utility associated with Alternative i, is v_{ik} and the vector of attributes is Z_i. The cost of Alternative i is p_i, income is y_k, and a random error term with zero mean is $\mathcal{E}_{jk}$.

An individual is assumed to maximize their utility when making a choice between two exclusive Alternatives i and j. The respondent chooses the alternative that brings higher utility. The probability that a consumer will choose Alternative i from a choice set is

$$P_{ik} = P\left[v_{ik}(Z_i, y_k - p_i) + \mathcal{E}_{ik} > v_{jk}\left(Z_j, y_k - p_j\right) + \mathcal{E}_{jk}\right];\ \forall j \in C \tag{2}$$

Utility is assumed as a linear function of the attributes in the design. The utility of choosing Alternative i in an experiment with three attributes, including a monetary attribute, the utility function is

$$v_{ik} = \beta_1 z_{i1} + \beta_2 z_{i2} + \lambda(y_k - p_i) + \mathcal{E}_{ik} \tag{3}$$

where the vector of preference parameters for nonmonetary attributes is denoted as β and the marginal utility of money is denoted as λ. (Holmes et al. 2017)

2.3 Multinomial logit model

When using a RUM model, it is assumed that errors are independently and identically distributed, and they follow a Gumbel distribution. The difference between two Gumbel distributions leads to a logistic distribution, yielding a conditional or multinomial logit model. The multinomial logit model relies on restrictive assumptions, and its popularity derives primarily from its simplicity estimations.

If a choice experiment to be analysed consists of one choice set with *N* alternatives and the error are distributed as Type 1 extreme value, the multinomial logit model applies. The probability of respondent *k* choosing Alternative *i* is

$$P_{ik} = \frac{\exp(\mu \mathrm{v_{ik}})}{\sum_{j=1}^{N} \exp\left(\mu v_{jk}\right)} \tag{4}$$

where μ reflects the variance of the unobserved part of utility, and is defined as a scale parameter. The two important properties of the multinomial logit model are: "the alternatives are treated as independent, and the modelling of taste variation among respondents is limited." (Holmes et al. 2017)

There are two limitations in the use of multinomial logit model. The first concern occurs because of the assumptions about the independently and identically distributed error terms. This independence of irrelevant alternatives property states that "the ratio of choice probabilities between two alternatives in a choice set is unaffected by other alternatives in the choice set." This assumption can be tested by removing one alternative and re-estimating the model, and comparing the choice probabilities (Hausmann & McFadden 1984). If the independence of irrelevant alternatives is satisfied, the ratio of choice probabilities should not be affected by whether another alternative is in the choice set or not. An alternative model should be applied if the assumption of independence of irrelevant alternatives is violated. (Holmes et al. 2017)

The second issue with the multinomial logit model is how it handles unobserved heterogeneity. The observed heterogeneity can be included into the model by allowing interaction between socio-economic characteristics and attributes of the constant terms or alternatives. Nevertheless, the assumption about independently and identically distributed error terms is gravely restricting with respect to unobserved heterogeneity. (Holmes et al. 2017)

3 Survey design and data

3.1 Survey questionnaire

The survey questionnaire comprises of four parts: transportation and driving, electric vehicle, future vehicle purchase, and demographics. The first part, transportation and driving, contains questions about the respondent's current vehicle and driving patterns. With this part, knowledge is gained of the respondents' vehicle preferences and driving ranges on daily and yearly levels. The second part, electric vehicle, has questions that yield information on electric vehicle experience, interest, and a possibility to home and/or workplace electric charging. The third part, future vehicle purchase, reveals the timeframe of next vehicle purchase, contains the choice experiment, and questions about electric vehicle features, attitudinal statements and risk aversion questions. The choice experiment attributes are CO_2-eq emissions from driving (g/km), driving range (km), electric battery fast charging time from 0 to 80% (min), driving costs (€/1000 km), and purchase price (€). The attributes are described thoroughly before the choice experiment. The last part, demographics, provide the information that can be used to categorize the respondents to separate segments based on e.g. their municipality, education, age, and gender and thus determine the most potential electric vehicle adopter group. The survey questionnaire was designed during the summer and autumn of 2019 and was conducted in spring 2020. Data was collected using a consumer panel of a commercial polling company TNS Kantar.

The questionnaire is based on a literature review on relevant attributes of electric vehicles and the information on current cars available in the market. Familiarizing with the current vehicle fleet in Finland, electric vehicle charging infrastructure, and policy instruments enabled shaping the survey questionnaire into the Finnish environment. Reports about electric vehicle surveys (Trafi researches 3/2017, Trafi publications18/2018), revealed information on attitudes and knowledge of the Finnish citizens regarding electric vehicles. To develop the questionnaire further, think-aloud interviews were conducted. The interviews gave insight into respondents' understanding of the questions.

The respondents were divided into three groups, small, medium, or large, based on their current vehicle size. The respondents answered to six randomized choice tasks according to their size group. Choice tasks were a combination of attribute levels (in table 1), which differ based on the size group.

There are three attribute levels for each vehicle size category, except for purchase price. Purchase price has six levels, which are same for all vehicle types within the size category. The tailpipe CO_2 emissions for battery electric vehicles are zero in all sizes and levels. Charging time has same levels for both electric vehicles in all size categories.

Table 1. Attributes and their levels

Attribute	Alternative	Small			Medium			Large		
		Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
CO2 emissions	BEV		0			0			0	
(g/km)	PHEV	28	38	48	38	48	58	38	48	58
	CV	128	140	148	142	150	162	148	160	172
Driving range	BEV	200	250	300	200	350	500	400	500	600
(km)	PHEV	500	590	680	500	590	680	500	590	680
	CV	500	650	800	500	650	800	500	650	800
Charging time (min)	BEV & PHEV	10	30	60	10	30	60	10	30	60
Driving cost	BEV	12	17	22	16	21	26	20	25	30
(€/ 1000 km)	PHEV	26	31	36	26	31	36	30	37	45
	CV	69	84	99	78	98	118	87	112	137
Purchase price (€)	All	11 000, 14 000, 18 000, 23 000, 29 000, 35 000			17 000, 20 000, 24 000, 29 000, 35 000, 41 000			41 000, 44 000, 48 000, 53 000, 59 000, 65 000		

An example of a choice task is presented in figure 2. The choice is made between options A, B, and C based on the attribute levels. The choice experiment design was created with the Ngene software.

	A	B	C
	Battery electric vehicle	Plug-in hybrid vehicle	Conventional vehicle
CO2-emissions	0 g/km	48 g/km	162 g/km
Driving range	500 km	500 km	650 km
Fast charging time	10 min	30 min	
Driving cost	26 €/ 1000 km	36 €/ 1000 km	78 €/ 1000 km
Purchase price	41 000 €	24 000 €	17 000 €

Figure 2. Choice task example, medium-size group

Prior the survey questionnaire, a pilot survey of 91 respondents was conducted. Based on the data analysis, electric charging infrastructure distance (km apart from each other in main/national roads) was removed from the choice experiment since it was not statistically significant and removing it made the choice experiment design clearer. Furthermore, questions about daily transportation routines were removed due to Covid-19 pandemic that changed the routines immensely, and a question to measure risk aversion was added.

3.2 Data

The data comprises 409 respondents from across Finland. The survey questionnaire was targeted to over 18 years old driving licence holders. The responses were collected until the 409 responses were acquired, and therefore there are no non-respondents. The representativeness of the sample to the Finnish population with driving license was tested regarding age, gender, and living county. The respondents' age profile fits well to the Finnish population regarding the age group 30 to 64 years. Of the respondents and of the Finnish driving licence holders, 60.9% are 30 to 64 years old. Under 30 years old (respondents 13.0% vs. Finnish driving licence holders 16.8%) and at least 75 years old (3.4% vs. 6.5%) respondents are under-represented, and 65 to 74 years old are over-represented (22.7% vs. 15.7%). The respondents' gender distribution is nearly aligned with the Finnish population. The male gender is slightly over-represented in the data (56.0% vs. 52.9%). Regarding the living county, the whole mainland Finland is well presented, except the Uusimaa region is slightly over-represented (33.0% vs. 28.9%) and the Northern Ostrobothnia under-represented (4.6% vs. 7.4%). The results of the study can be generalized to the whole country.

Roughly, half (52.1%) of the respondents are at least 50 years old, 44.0% are female, 44.4% have a university degree, 33% live in the county of Uusimaa, 21.5% in the rest of Southern Finland, 25.2% in Western Finland and 20.3% in Northern or Eastern Finland. Of the respondents, 22.7% live in a row or semi-detached house, and 40.3% live in a detached house. Roughly, a third (28.6%) of the respondents are pensioners, and a fourth (25.7%) are employees. Respondents live in relatively small households, 40.8% have a household of two, and 28.6% a household of one. Almost half (46.2%) of the respondents live in a city. Table 2 presents the socio-demographic characteristics of the respondents.

Table 2. Socio-demographic characteristics of the respondents, n=409

	%		%
Age		Residential area	
18-29 years	13.0	Uusimaa	33.0
30-49 years	34.9	Rest of Southern Finland	21.5
50-69 years	38.7	Western Finland	25.2
Over 70 years	13.4	Northern or Eastern Finland	20.3
Gender		Åland islands	0.0
Female	44.0	Living environment	
Male	56.0	Countryside	19.6
Education		Rural local centre	12.2
Basic education	6.8	Suburb	20.8
Vocational upper secondary education and training	22.7	City	46.2
General upper secondary education	8.3	I don't know	1.2
College level vocational undergraduate degree	16.9	House type	
Bachelor's degree	24.4	Block building	36.2
Master's degree or higher of university or college	20.0	Row or semi-detached house	22.7
Other	0.7	Detached house	36.4
Occupational group or situation		Detached house in a farm land	3.9
A leading position employed by another	3.2	Other	0.7
Senior officer	15.4	Living situation	
Junior officer	9.0	With parents	3.2
Employee	25.7	Alone	27.9
Entrepreneur or self-employed	4.6	Together with partner	37.2
A farmer	1.2	With partner and children	25.4
Unemployed	4.2	Single parent with children	1.5
In school or a student	4.4	Other	3.7
Pensioner	28.6	I don't want to say	1.2
Stay-at-home parent	1.0	Household size	
Other	1.0	1	28.6
Cannot say	1.7	2	40.8
Household's total annual net income		3	12.0
Less than 20 000 €	8.1	4	13.0
20 001 - 35 000 €	15.4	5	4.4
35 001 - 50 000 €	15.6	6 or more	1.2
50 001 - 85 000 €	26.7		
85 001 - 100 000 €	10.8		
Over 100 000 €	9.5		
No answer	10.3		
I don't know	3.7		

4 Results

4.1 Current vehicle and driving habits

One-third (33.1%) of the respondents stated that they had purchased their vehicle as new, whereas two-thirds (65.8%) had purchased their vehicle as pre-owned. On average, the vehicle has been 4.8 years in the household. Most often, the current vehicle was gasoline (56.5%), followed by diesel (32.4%), plug-in hybrid vehicle (6.9%) and other kind of hybrid vehicle (2.2%). The respondents were used to drive in different environments: 29.7% drove mostly outside the cities (extra-urban driving, i.e. motorways and roads), 32.6% mostly in cities (urban), and 36.1% equally both combined. The vehicle was in use on average four to five days per week. According the survey results, the respondents (64.7%) typically drove less than 50 km in a day. The longest trip, excluding overnight stays, during the previous 12 months was on average 462 km, and most typically ranged from zero to 1500 km. The average annual kilometres driven were 13 995 km.

Majority (96.1%) of the respondents knew the fuel or electricity consumption of their vehicle (l/km or kWh/km), and more than half (56.0%) knew the CO_2 emissions from driving. The respondent was alone responsible for vehicle purchase choice in 42.2 % of the responses, the respondents' spouse alone in 8.0% and both together in 48.5% of the responses. More than half (58.5%) of the respondents are going to purchase their next vehicle in less than five years and 10% stated that they are not going to purchase a new vehicle. One-third (32.1%) of the respondents have not read or heard about electric vehicles before. Of the respondents 21.7% have searched for information about electric vehicles, 11.7% have considered buying an electric vehicle, and 12.5% have driven an electric vehicle. Table 3 presents the vehicle and driving related characteristics of the respondents.

Table 3. Current vehicle and driving habits

	%		%
Number of vehicles in household		Driving kilometres per day	
0	7.8	Less than 20	22.0
1	52.8	20-49	42.7
2	29.1	50-99	20.7
3 or more	10.3	100-199	9.5
Current vehicle		Over 200	0.8
Purchase		I don't know	2.7
New from dealership	27.5	Knowledge of vehicle's consumption	
Leasing, New from dealership	5.6	Knows	96.1
Pre-owned from dealership	46.2	Does not know	3.9
Pre-owned from elsewhere	19.6	Knowledge of vehicle's CO_2 emissions from driving	
How long have you owned the vehicle		Knows	56.0
Less than a year	17.5	Does not know	44.0
1	9.5	Who is responsible for vehicle purchase?	
2	17.2	The respondent alone	42.2
3	14.9	Respondents spouse alone	8.0
4	6.9	Both together	48.5
5	7.2	I don't know	1.1
6	4.2	Future vehicle purchase	
7	2.7	Less than a year	8.6
8	4.8	One to two years	21.0
9	2.9	Three to five years	28.9
10 or more	11.4	Over five years	9.8
I don't know	0.8	Not going to purchase a vehicle	10.0
Fuel		I don't know	21.8
Gasoline	56.5	Electric vehicle charging possibility at home	
Diesel	32.4	Yes	31.5
Plug-in hybrid	6.9	No	57.9
Hybrid	2.2	I don't know	10.6
Gas	1.1	Electric vehicle charging possibility at work	
Flexfuel	0.8	Yes	17.4
Battery electric vehicle	0.3	No	72.8
Driving type		I don't know	9.8
Extra-urban	29.7	I heard about electric vehicles first time in this survey	0.5
Urban	32.6	I have heard or read about electric vehicles before	67.9
Both equally	36.1	I have searched information about electric vehicles	21.7
Don't know	1.6	My friend owns an electric vehicle	14.4
Vehicle in use, days per week		I have considered buying an electric vehicle	11.7
Six to seven	41.4	I have driven an electric vehicle	12.5
Four to five	33.7		
Two to three	19.9		Mean
One	1.1	Kilometres driven in a year	13995
Varies	4.0	Longest trip during last 12 months	461.6

4.2 Attitudes and perceptions of electric vehicles

A selection of attitudinal statements was presented to the respondents using the Likert scale from "Strongly agree" to "Strongly disagree". The responses to the attitudinal statements are presented in figure 3. The most agreed (strongly agree and agree) statement is, "I try to reduce my carbon footprint" (73.3%). Second most agreed is "Electric vehicles can significantly reduce CO_2 emissions from road traffic" (65.5%), followed by "Biogas is an environmental fuel option" (64.1%), "Electric vehicle production chain should be more transparent" (62.6%), and "It is more reasonable to wear out an old vehicle rather than purchase a new electric vehicle" (60.1%).

The most often disagreed statements (disagree or strongly disagree) were: "Global warming, and its effects are exaggerated" (54.8%), "The share of passenger vehicle traffic in Finland's total emissions is small, and therefore it is not worth investing in its emission reductions" (40.1%), "I would purchase an electric vehicle if I could charge it at home or at workplace" (38.4%), and "It is convenient to rent a car for holidays" (36.9%).

The questions respondents answered neither agree nor disagree the most were: "It is more reasonable to convert a conventional vehicle to bioethanol or gas vehicle rather than buy an electric vehicle" (35.5%), "My closest friends and family think that driving an electric vehicle is a good thing" (35.0%), "Reducing emissions from air traffic is more important than from road traffic" (33.0%), "I like to test new technology" (32.0%), and "Cheaper biodiesel would be the best solution to reduce emissions from passenger vehicle traffic" (31.3%).

The questions with the highest proportions of "I don't know" answers were: "My closest friends and family think that driving an electric vehicle is a good thing" (14.2%), "It is more reasonable to convert a conventional vehicle to bioethanol or gas vehicle rather than buy an electric vehicle" (13.2%), and "Driving a battery electric vehicle does not reduce emissions because of its emissions from battery making" (11.7%).

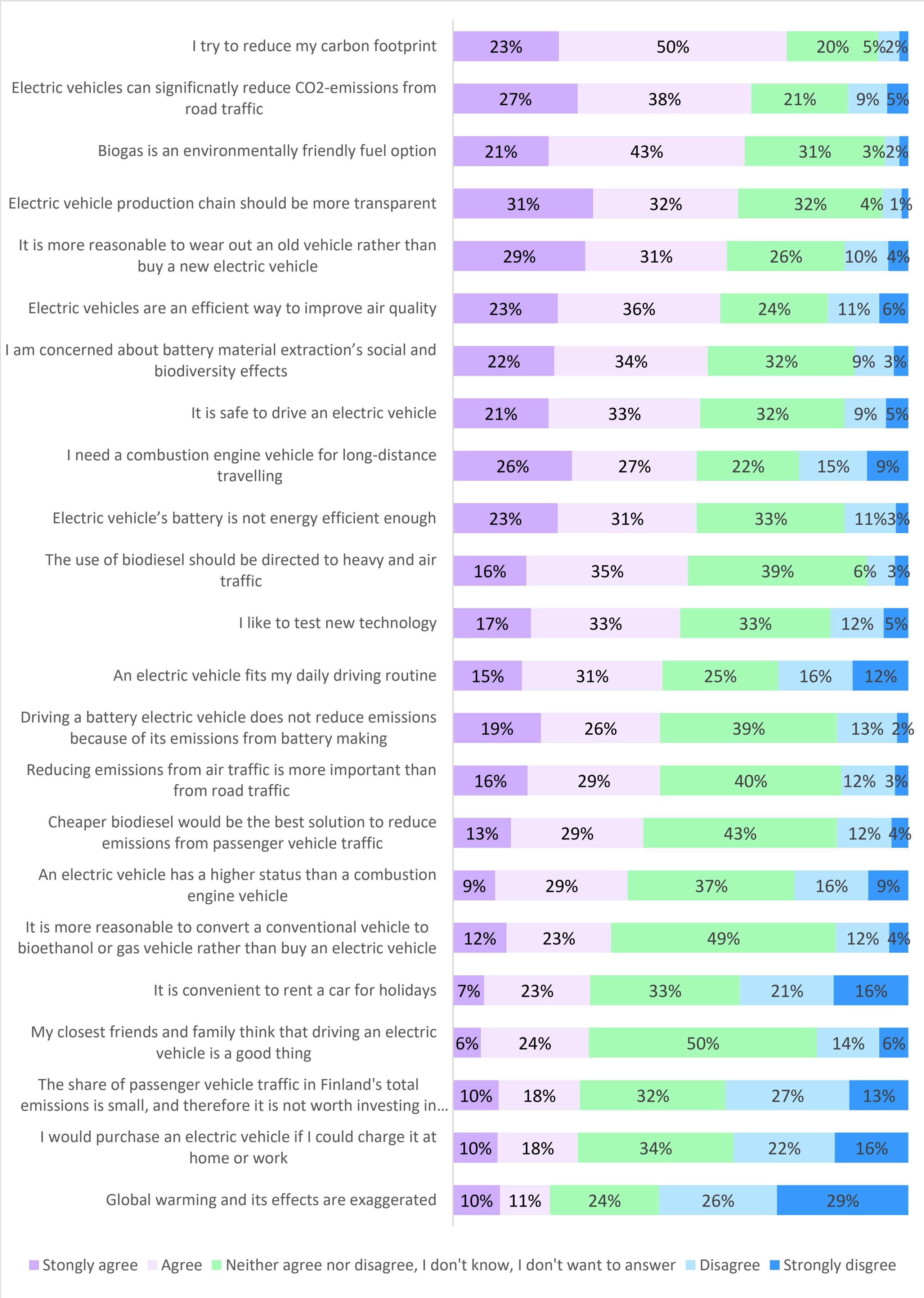

Figure 3. Attitudinal statements.

In order to examine the relationship between the attitudinal variables reflected by statements concerning electric vehicle adoption, a factor analysis was conducted. Twenty-four statements were reduced to five factors, which are presented in table 4. For ease of interpretation, the factor loadings smaller than 0.3 have been removed from the table. Factor 1 ('EV positive') reflects electric vehicle and technology positive attitudes. Factor 2 ('Remiss climate change') reveals disregard of global warming and ignorance towards passenger vehicle emissions. Factor 3 ('Responsibility') reflects the awareness of individual carbon footprint and concern about emissions, social and biodiversity effects of electric vehicle manufacturing. Factor 4 ('Biodiesel and biogas positive') shows environmental awareness with positive biodiesel and biogas perceptions. Factor 5 consists of statements that are not well related to each other and the interpretation is therefore difficult. Cronbach's alpha, which measures internal consistency, is 0.137 for this factor. Values greater than 0.6 indicate acceptable internal consistency. There is no statistically significant correlation between any of the factors.

Table 4. Respondent's attitudes on electric vehicle issues and the loads of statements to extracted factors.

	Extracted factors				
Statement	1	2	3	4	5
An electric vehicle fits my daily driving routine	**0.745**				
Electric vehicles are an efficient way to improve air quality	**0.721**	-0.405			
I would purchase an electric vehicle if I could charge it at home or work	**0.707**				
Electric vehicles can significantly reduce CO_2 emissions from road traffic	**0.698**	-0.381			
I like to test new technology	**0.679**				
It is safe to drive an electric vehicle	**0.671**				
My closest friends and family think that driving an electric vehicle is a good thing	**0.537**				
An electric vehicle has a higher status than a combustion engine vehicle	**0.491**				-0.429
It is more reasonable to wear out an old vehicle rather than buy a new electric vehicle		**0.425**		0.357	
Global warming and its effects are exaggerated		**0.791**			
The share of passenger vehicle traffic in Finland's total emissions is small, and therefore it is not worth investing in its emission reductions		**0.777**			
I try to reduce my carbon footprint		-0.506	**0.513**		
Electric vehicle production chain should be more transparent			**0.646**		

I am concerned about battery material extraction's social and biodiversity effects			**0.819**		
Driving a battery electric vehicle does not reduce emissions because of its emissions from battery making		0.460	**0.529**		
The use of biodiesel should be directed to heavy and air traffic				**0.645**	
Biogas is an environmental fuel option			0.347	**0.581**	
Cheaper biodiesel would be the best solution to reduce emissions from passenger vehicle traffic				**0.664**	
It is more reasonable to convert a conventional vehicle to a bioethanol or gas vehicle rather than buy an electric vehicle				**0.593**	
It is convenient to rent a car for holidays					**-0.649**
Reducing emissions from air traffic is more important than from road traffic				0.311	**0.328**
Electric vehicle's battery is not energy efficient enough				0.301	**0.572**
I need a combustion engine vehicle for long-distance travelling					**0.643**
Cronbach's alpha	0.852	0.677	0.622	0.603	0.137

Factors 'EV positive', 'Responsibility', and 'Biodiesel and biogas positive' can be seen as environmentally friendly, and factor 'Remiss climate change' as the opposite. These environmentally friendly factors differ in their opinion of electric vehicles. Whereas the 'EV positive' factor represents the accepting attitude towards electric cars, the 'Biodiesel and biogas positive' factor represents the ideology that biogas and biodiesel are better fuel options to reduce emissions than electricity. The 'Responsibility' factor in itself cannot be categorized as EV positive or EV negative, but the concern of the electric vehicle battery manufacturing can be interpreted.

The positive factor loadings overlap in all factors. Of the respondents who have positive factor loading towards factor 'EV positive', 48% have also positive factor loading towards factor 'Remiss climate change'. This indicates that almost half of the respondents in 'EV positive' factor are open to the idea of an electric vehicle. Nevertheless, they still have doubts about the reasonability to purchase a new electric car rather than wear out their current vehicle, the amount of emissions from passenger vehicles, and the exaggeration of climate change. The 'EV positive' factor could be interpreted as a possible electric vehicle adopter. However, when the respondents that have positive factor loadings towards this factor but not to the 'Remiss climate change' and 'Biogas and biodiesel positive' factors are examined closer, it can be noticed that over a third of the non-participants are a part of this group. Therefore, the assumption about potential electric vehicle adoption cannot be made for the factor 'EV positive'. Of the respondents who have positive factor loading towards factor 'Responsibility', 48% have positive factor loading towards factor 'EV positive' and 53% towards factor 'Remiss climate change'. Therefore, it cannot be interpreted if the responsibility is the leading motive or just a disguise to cover up the disregard for electric vehicles.

4.3 Non-participants and reasons for not choosing an electric vehicle

Nine percent of the respondents never chose an electric vehicle in the choice experiment. These respondents are called non-participants. The comparison of the socio-demographic characteristics of the non-participants and other respondents reveal that, non-participants are more often over 50 years old (67.6% vs. 50.5%), more often males (81.1% vs. 53.5%), have lower education level (no university degree 73.0% vs. 53.8%), more respondents with annual income of 85 001-100 000€ (21.6% vs. 9.7%), less frequently live in the rural local centres (0.0% vs. 13.4%), more often live in a detached house (54.0% vs. 39.0%) but not in a row or semi-detached house (10.8% vs. 23.9%). When the vehicle-related characteristics of the non-participants are compared to the rest of the respondents, the non-participants buy their vehicles more often as pre-owned from elsewhere (30.6% vs. 16.9%), have less any kind of electric vehicles including not rechargeable hybrids (0.0% vs. 9.4%), and can charge their vehicle at workplace less frequently (5.4% vs. 16.7%). Non-participants state that they have read and heard about electric vehicles before this survey more often than the rest of the respondents (81.1% vs. 66.5%), fewer of them have searched for information about electric vehicles (5.4% vs. 23.6%) and none of them has considered buying an electric vehicle (0.0% vs. 13.0%). The non-participants drive on average more on a yearly level than other respondents (18 600 km vs. 13 500 km). These differences between the non-participants and the rest of the respondents are statistically significant, at least at a 10% level.

Regarding the descriptive statistics of the non-participants, 29.7% of the them are pensioners, 51.6% live in a city and 31.6% in the countryside, 48.6% live in a detached house, and 37.8% live together with their partner in a household of two. More than half (54.1%) of the non-participants have one vehicle in their household, 75.0% buy their vehicle pre-owned, 56.8% of their current vehicles run with gasoline, 37.8% with diesel, and 2.8% with gas. Roughly, half (47.2%) of them drive six to seven days per week, 47.2% do not know their vehicles CO_2-consumption, 52.8% are alone responsible for the vehicle purchase, 67.6% cannot charge an electric vehicle at home, and 81.1% at the workplace.

Of the non-participants, 83.8% agreed or strongly agreed with the statement “It is more reasonable to wear out an old vehicle rather than buy a new electric vehicle”, 81.1% agreed or strongly agreed with the statement “I need a combustion engine vehicle for long-distance travelling”, and 81.1% with the statement “Driving a battery electric vehicle does not reduce emissions because of its emissions from battery-making”. Of the non-participants, 70.3% disagree or strongly disagree with the statement “I would purchase an electric vehicle if I could charge it at home or work”, 67.6% with the statement “It is convenient to rent a car for holidays”, and 67.6% with the statement “An electric vehicle fits my daily driving routine”.

The comparison of the non-participants’ and other respondents’ responses to the attitudinal statements (figure 4) reveal that the statement with the most considerable difference in the level of agreeing is “Electric vehicles can significantly reduce CO_2 emissions from road traffic” (24.3% vs. 69.9%), the non-participants agreeing less with this statement. The significant differences in the statements are in the following: “An electric vehicle fits my daily driving routine” (5.4% vs 50.0%), “Electric vehicles are an efficient way to improve air quality” (18.9% vs. 62.6%), and “It is safe to drive an electric vehicle” (16.2% vs. 58.1%). The largest difference in the level of agreeing, with non-participants agreeing more with the statement, are “Driving a battery electric vehicle does not reduce emissions because of its emissions from battery-making” (81.1% vs. 41.9%), “The share of passenger vehicle traffic in Finland’s total emissions is small, and therefore it is not worth investing in its emission reductions” (62.2% vs. 24.5%), “Global warming and its effects are exaggerated” (54.1% vs. 18.0%), and “I need a combustion engine vehicle for long-distance travelling” (81.1% vs. 50.8%).

The distribution of the answers to the statements are statistically significantly different between non-participants and other respondents with respect to all statements except three. These statements are “Electric vehicle production chain should be more transparent”, “Biogas is an environmental fuel option”, and “Reducing emissions from air traffic is more important than from road traffic”.

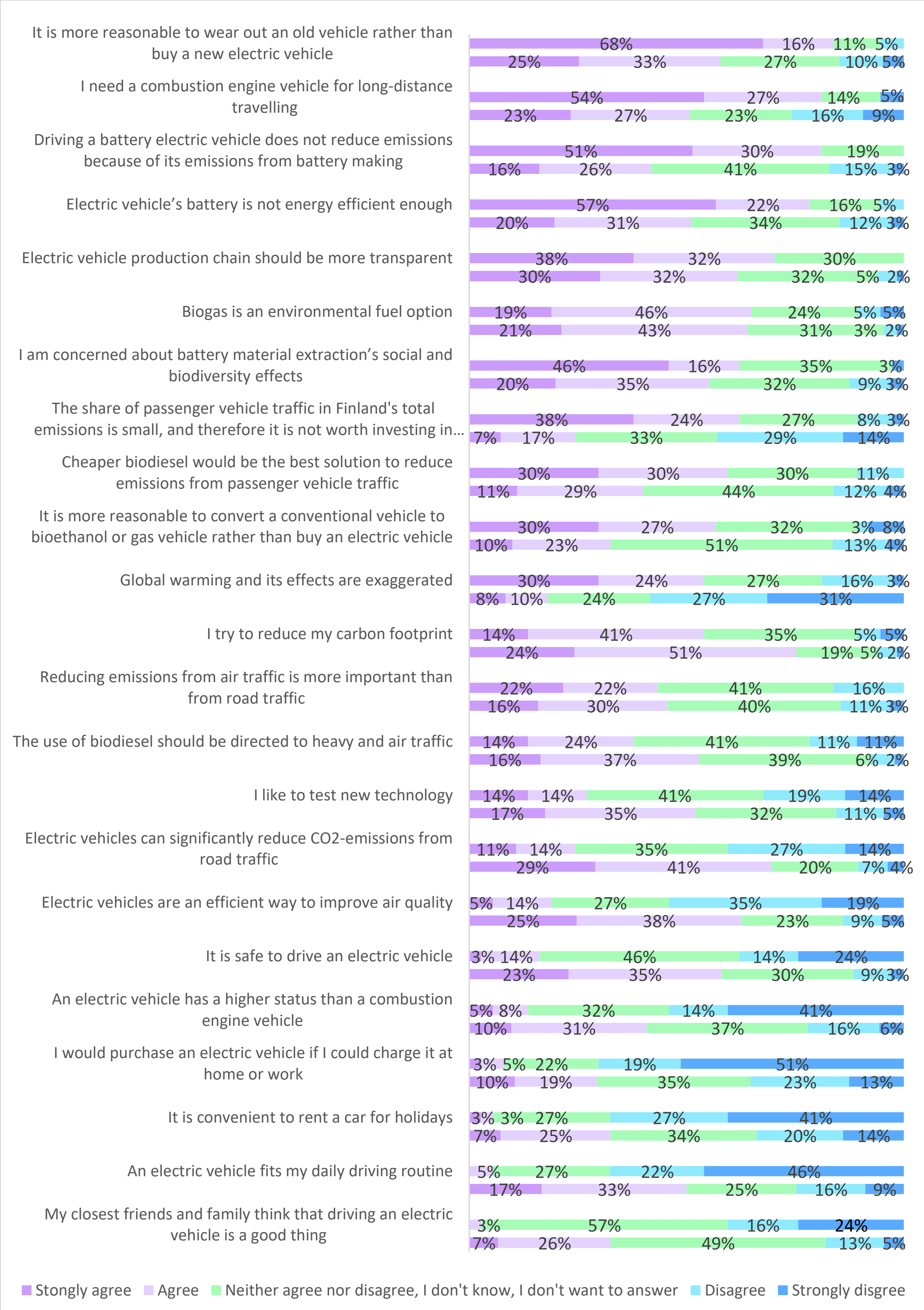

Figure 4. Attitudinal statements. Non-participants above and rest of the respondents below

If a respondent chose a conventional vehicle in at least one choice task, they were asked for the reason(s) for not choosing an electric vehicle, using a pre-determined list of reasons and an open question. The majority (60.3%) of the respondents who chose a conventional vehicle in the choice task answered that the purchase price is too high, followed by the shortness of driving range (42.1%). More than one-third (35.9%) answered, "CO_2 equivalent emissions from manufacturing electric vehicles and their batteries are too high", 34.4% "There is not going to be enough charging points on main roads" and 34.4% "Electric vehicle charging is too difficult". Of these respondents, 12.9% do not want to drive an electric vehicle. Eleven percent had other reasons related to electric vehicle's technical issues, charging time, price, sustainability and emissions, or attitude against an electric vehicle.

When the non-participants are separated from the rest of the respondents (figure 5), the main reason for not choosing an electric vehicle is the shortness of driving range. Of the non-participants 59.9% stated that electric vehicle's driving range is too short, 32.4% do not want to drive an electric vehicle, and for 29.7%, the purchase price is too high. In comparison to the rest of the respondents, the non-participants are more prejudiced against electric vehicles. The 'other' reasons included concerns about charging time and charging possibilities, and technical related issues.

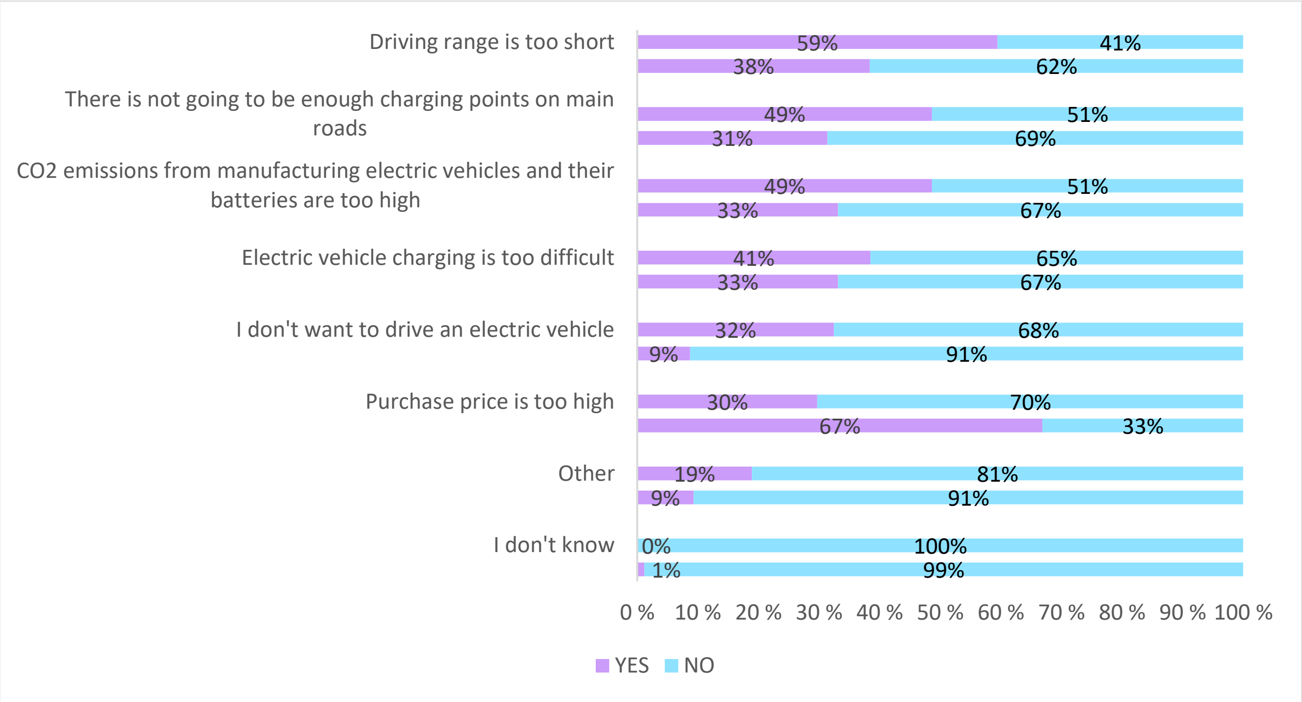

Figure 5. Reasons not to choose an electric vehicle. Non-participants above and rest of the respondents below.

When the respondents who chose the shortness of the driving range as a reason for not selecting an electric vehicle are compared to the respondents who did not choose this reason, it was found that they drive on average more kilometres in a year (17 000 km vs. 13 000 km), on average longer trips a time (550 km vs. 425 km) and greater portion drives more than 50 km a day (37.5% vs. 26.4%). Of these respondents, a larger share lives in Northern or Eastern Finland (25.0% vs. 11.6%).

Those respondents who stated that the reason for not choosing an electric vehicle was that they do not believe there will be enough charging points on main roads drive more frequently less than 50 km a day (69.4% vs. 57.7%) compared to the respondents who did not choose this reason. Of these respondents, a greater share lives elsewhere than Southern Finland (43.1% vs. 59.9%).

4.4 Preferences for vehicle attributes

The choice experiment data was estimated with Nlogit software, and the multinomial logit model was the basis for the analysis. The model comprises of attributes: CO_2 emissions from driving, driving range, fast charging time, driving cost, and purchase price. Constants B1 and B2 represent the battery electric vehicle and plug-in hybrid vehicle, in comparison to the conventional vehicle. The analysis aimed to determine how the attributes affect the vehicle purchase choice. The results of the base model are presented in table 5.

Table 5. Results of the base model

Discrete choice multinomial logit model

Log likelihood function -2072.90254
Estimation based on N= 2208
R-squared 0.0864

	Coefficient	Standard error	Significance
B1	1.35696	.79964	*
CO_2	.00617	.00410	
RANGE	.00185	.00030	***
TIME	-.00650	.00153	***
DRCOST	-.00273	.00290	
PRICE	-.04820	.00289	***
B2	1.57646	.58714	***

***, **, * → Significance at 1%, 5%, 10% level.

In table 5, Mc Fadden's pseudo R-squared shows the proportion of total variability explained by the model. R-squared varies between zero and one. When the value is higher, more variability is explained, and thus the model is better.

Coefficient shows the magnitude and the direction of the effect of the attribute on the choice. If the coefficient is positive, the utility that the respondent derives from that alternative increases as the level of attribute increases and vice versa with a negative coefficient. Constant coefficients capture the variation in preferences that cannot be explained by the attributes. If the constant's coefficient is positive, the respondents are on average willing to purchase that vehicle. The stars reflect whether the variable's effect is statistically significant at 1%, 5%, or 10% level. (Stock & Watson 2020)

The estimated results (table 5) revealed a tendency to choose a plug-in hybrid as the coefficient for B2 is larger than the coefficient for B1. The model shows that the driving range's coefficient is positive and significant; thus, a longer driving range increases the probability of choosing an electric vehicle. The coefficients for charging time and purchase price are negative and significant, which means that when charging time or price increases, the probability to choose an electric vehicle decreases. The purchase price has the greatest effect on the vehicle purchase choice. The coefficients of CO_2 emissions and driving costs are not significant in this model, thus have no effect on the choice. The McFadden's pseudo R-squared value is 0.0864.

4.5 Preference heterogeneity for electric vehicles

All the variables from survey questions and socio-demographic characteristics were analysed to see which of them were statistically significant for the electric vehicle choice. The variables were tested for battery electric vehicle and plug-in hybrid vehicle separately. The statistically significant factors for electric vehicles are collected in table 6. Zero as a coefficient expresses that there is no statistically significant effect on the choice.

Table 6. Significant factors in electric vehicle purchase choice

	BEV		PHEV	
	Coefficient	Significance	Coefficient	Significance
Age				
Less than 50	+	***	-	***
50 or over	-	***	+	***
Gender				

Female	+	***	+	**
Male	-	***	-	**
Education				
Basic education, high school level education	-	**	0	
Bachelor’s or Master’s degree, or PHD	+	***	0	
Household’s total annual net income				
Less than 20 000€	+	***	-	***
Less than 35 000€	+	***	0	
85 001 – 100 000€	-	***	0	
Over 100 000€	+	***	-	**
Residential area				
Uusimaa	+	***	-	*
Other Southern Finland	-	*	0	
Northern or Eastern Finland	-	*	+	***
House type				
Row/semi-detached	-	*	0	
Detached house	0		-	***
Household size				
1-2	-	***	+	***
3+	+	***	-	***
Number of vehicles in household				
0	+	**	0	
Less than two	0		+	***
Three or more	0		-	***
Was the current vehicle new or pre-owned when it was purchased				
New	0		+	***
Pre-owned	0		-	***
How long the vehicle has been owned				
Four years or less	0		+	***
More than four years	0		-	***
Fuel type of the current vehicle				
Gasoline	+	***	-	***
Diesel	-	***	0	
PHEV	-	*	+	***
Other hybrids	0		+	*
Driving type				
Urban driving	+	***	0	
Extra-urban driving	-	***	0	
Both	-	***	0	
Vehicle in use, days per week				
One to three	+	**	0	
Four to five	-	**	+	**
Four to seven	-	***	0	
Six to seven	0		-	*
Driving kilometres per day				
Less than 20 km	+	***	0	
More than 50 km	-	***	0	
Not driving regularly	+	***	-	**

Longest trip during last 12 months				
<460	+	***	0	
≥460	-	***	0	
Kilometres driven in a year				
<15 000 km	+	***	0	
≥15 000 km	-	***	0	
Knowledge of the vehicle's consumption				
Knows	-	***	0	
Does not know	+	*	0	
Knowledge of the vehicle's CO_2 emissions				
Knows	-	***	+	*
Does not know	+	**	-	**
Possibility to charge				
At home	-	*	+	***
At work	0		+	***
Who is responsible for car purchase?				
The respondent alone	-	**	-	***
Respondent's spouse alone	0		+	**
Spouse alone or both together	0		+	***
Future vehicle purchase				
1-5 years	-	***	+	***
Over 5 years	+	**	0	
How well do you know electric vehicles				
Only read or heard, not anything else	-	***	-	**
I have searched for information about electric vehicles	+	**	0	
I have considered buying an electric vehicle	+	***	0	
I have driven an electric vehicle	-	***	+	***

***, **, * → Significance at 1%, 5%, 10% level.

The battery electric vehicle and plug-in hybrid vehicle attributes, and socio-demographic and vehicle related variables were combined into the same econometric model (table 7) sequentially until only simultaneously statistically significant variables were left. All variables are interactions between the variable and the corresponding electric vehicle. Thus, the coefficients cannot be compared between a battery electric vehicle and a plug-in hybrid vehicle. The following variables were found to increase the probability to choose BEV: living county Uusimaa, Bachelor's or Master's degree or higher, gender woman, age less than 50 years, driving less than 50 km per day. The following variables were found to increase the probability to choose PHEV: residence in Northern or Eastern Finland, Bachelor's or Master's degree or higher, row or semi-detached house, gender woman, and the possibility to charge an electric vehicle at home. Gender has the most significant effect on the choice in both electric vehicle types, following age less than 50 years old for BEV and row or semi-detached house for PHEV.

Table 7. Results of the combined preference heterogeneity model

Discrete choice multinomial logit model			
Log likelihood function -1982.74663 Estimation based on N=2208 R-squared 0.1262			
	Coefficient	Standard error	Significance
B1	-.29548	.83744	
CO_2	.00438	.00422	
RANGE	.00197	.00031	***
TIME	-.00632	.00156	***
DRCOST	-.00421	.00299	
PRICE	-.05010	.00297	***
B2	.58292	.61193	
BEV			
UUSIMAA	.30292	.11570	***
UNIVERSITY DEGREE	.43992	.13238	***
FEMALE	1.02606	.13712	***
AGE LESS 50	.70271	.11049	***
LESS 50 KM /DAY	.35166	.11529	***
PHEV			
NORTH/EAST	.27251	.12127	**
UNIVERSITY DEGREE	.27569	.11354	**
ROW / SEMI-DETACHED	.60241	.10983	***
FEMALE	.80872	.11893	***
HOME CHARGING	.34426	.10062	***

***, **, * → Significance at 1%, 5%, 10% level.

Adjusted pseudo R-squared (0.126) in the combined preference heterogeneity model is higher than in the base model (0.086), indicating a better fit to the data of the combined preference heterogeneity model and that the new predictors add sufficiently to the model. The Log likelihood test was performed to compare the goodness of fit of the base model and the combined preference heterogeneity model.

$$\mathrm{LR} = 2 * \left(-1982.74663 - (-2072.90254)\right) = 2 * (-1982.74663 + 2072.90254) = 180.3116$$

The likelihood ratio test statistic is 180.31. With 10 degrees of freedom, the associated p-value is <0.00001, indicating that the combined preference heterogeneity model with ten more predictors fits significantly better than the base model (table 5) with only the original variables (attributes).

5 Discussion

This choice experiment study provides information for the Finnish electric vehicle policy planning by eliciting citizens' preferences for attributes of two electric vehicle alternatives: battery electric vehicle and plug-in hybrid vehicle.

Factors that affect the electric vehicle purchase choice

Regarding the effect of vehicle attributes on the willingness to buy an electric vehicle, purchase price, charging time, and driving range are significant factors in the vehicle purchase choice. In comparison to the conventional vehicle, the simultaneously significant factors that increase the probability that a person chooses a battery electric vehicle are Uusimaa as a county of residence, university degree, female gender, age less than 50, and driving less than 50 km/day. Similarly, significant factors that increase the probability of choosing a plug-in hybrid vehicle are the residence in Northern or Eastern Finland, university degree, row or semi-detached house, female gender, and a possibility for home charging. These results reflect the facts that the charging network is the densest in Southern Finland and more educated citizens are among the first to adopt electric vehicles. The results also show that citizens who drive less will be the most promising group to buy a battery electric vehicle in the future, while, for the rest of those interested in purchasing an electric vehicle, a more suitable option would be a plug-in hybrid. On average, the respondents preferred a plug-in hybrid for a battery electric vehicle, which is understandable since it has no uncertainty on the driving range. At the moment, the market share of plug-in hybrid vehicles is growing faster than that of battery electric vehicles in Finland. This, however, may become a challenge in the near future when the target is to increase the share of battery electric vehicles because plug-in hybrids do not reduce emissions from traffic as efficiently as battery electric vehicles (Ministry of Transport and Communications 2020).

Driving costs did not have a significant effect on the vehicle purchase choice. This could be due to the fact that the differences in the driving costs were not major enough in the choice tasks. When comparing the highest driving costs for medium-size conventional vehicle and the lowest driving costs for medium-size battery electric vehicle, the difference is only 1377€ in a year for those who drive 13 500 kilometres per year, which is the average amount a respondent drives. Compared to the difference in the purchase price, which was at the highest 24 000€ for medium-size vehicles, the driving cost savings from battery electric vehicle seem rather small. Higher gasoline and diesel prices could have given insight on the effect of a fuel tax to the purchase choice.

The findings of this study are well in line with the previous choice experiment studies on the adoption of electric vehicles. The literature review presents that short driving range, long battery charging time, and high purchase price are barriers for electric vehicle adoption. To our knowledge, CO_2 emissions from driving have not been studied in previous choice experiment studies. Driving costs, however, have been found to favour electric vehicle adoption (Axsen et al. 2009), but they did not affect the vehicle purchase choice in this study.

Reasons for not choosing an electric vehicle

Regarding the main reasons for not choosing an electric vehicle, the purchase price, driving range, and charging related problems were the primary concerns. Price is still the most significant barrier for electric vehicle adoption, except for the non-participants. Compared to the rest of the respondents, the non-participants less frequently stated that the purchase price was the reason for not choosing an electric vehicle. Thus, their resistance to electric vehicles is more a matter of principle than a monetary issue. It is not clear whether the resistance of electric vehicles is due to new and uncertain technology, the lifecycle emissions or the so called "snob effect". Average purchase price in 2019 for a new vehicle was 34 000€ and estimated average price for a pre-owned vehicle 6800€. (Finnish Information Centre of Automobile Sector 2020). Currently, the cheapest battery electric vehicle in Finnish markets costs less than 20 000€. However, because its promised driving range is 260 km, it is not enough to attract the average citizen due to range anxiety. Fortunately, more affordable electric vehicle models are arriving to the markets in future years. The purchase prices of battery electric vehicles are estimated to be at the same level as corresponding conventional vehicles by the mid-2020s. (Ministry of Transport and Communications 2021) The respondents seem to be familiar with the price development since the probability of choosing a battery electric vehicle increased if the respondents' vehicle purchase was planned to be after five years. Before the market prices of battery electric vehicles decrease to the level of conventional vehicles, the purchase subsidy is needed to accelerate the transition of the vehicle fleet. However, in 2018-2020, only 35.87% of the purchase subsidy budget (24M€ for 2018-2021) was used. The low rate of used subsidies imply that the subsidy of 2000€ is not high enough to sufficiently accelerate the electric vehicle adoption and therefore, the emission reductions from electric vehicles stay at a low level. (Ministry of Transport and Communications 2021) More research on the acceptable prices of battery electric vehicles is required to adjust the purchase subsidy properly. Furthermore, research on the price premium of electric vehicles is needed.

It is customary to buy a vehicle as pre-owned in Finland; hence, almost seventy percent of the respondents purchased their current vehicle as pre-owned. In 2020, 96 000 private passenger vehicles were newly registered, and 633 000 private passenger vehicles were bought as pre-owned. (Finnish Transport and Communications Agency 2021) The popularity of pre-owned cars in the Finnish vehicle markets is one reason why the vehicle fleet renewal is proceeding slowly, thus electric vehicles have not made a breakthrough in Finland, since there are not enough pre-owned electric vehicles in the vehicle markets. None of the non-participants has considered buying an electric vehicle and they buy their vehicles more often as pre-owned from private sellers. Since electric vehicles are not widely represented in pre-owned car markets excluding dealerships, it is rather unsurprising they have not considered buying an electric vehicle. Since respondents, who are 50 years or older, purchase more new vehicles than the younger respondents do, and respondents' older age negatively affects the battery electric vehicle's purchase choice, more pre-owned battery electric vehicles are needed to fasten the vehicle fleet's electrification. An option to address this problem would be to support the vehicle importers to bring reasonably priced, pre-owned battery electric vehicles from European countries such as Norway or Germany to the Finnish vehicle markets. In countries that electric vehicles have been used for longer, pre-owned electric vehicles are more frequently available.

When observing driving habits and their suitability with the charging of electric vehicles, it seems that not all citizens are aware of the potential of the electric vehicles. Even though almost all of the respondents drive less than 200 kilometres in a day, only half of the respondents claimed that an electric vehicle fits their daily driving routine. Most of the battery electric vehicles have a longer driving range than 200 kilometres. If the respondent can charge an electric vehicle at home or workplace, the respondents should be able to drive their daily routines with a battery electric vehicle. The respondents' high estimate of their driving range needs may be due to the lack of information on electric vehicle driving ranges and range anxiety. Egnér and Trosvik (2018) found that the increase in charging points decreases the range anxiety for those who cannot charge electricity at home.

Electric vehicle charging is possible at home for one-third and at work for one-fifth of the respondents. The question about home and work charging was slightly ambiguous: it may have been interpreted as "Can you currently charge your vehicle at home?" or "Is there a possibility to install a charging point at your home?". Almost one-third of the respondents stated that they would purchase an electric vehicle if they could charge it at home or workplace. If charging is not possible at home, the threshold to purchase an electric vehicle is greater. The lack of home charging has been considered one of the main barriers for the electric vehicle adoption (Ministry of Transport and Communication 2021).

Over half of the respondents said they need a combustion engine vehicle for long-distance traveling. For these respondents, on average, the longest trip by car during the last 12 months was 335 kilometres. Depending on the battery electric vehicle and the driving temperature, 335 kilometres could be driven with zero to one fast charging stops if the battery is full at the start of the journey. The respondents either do not know how long the fast charging takes, think it is too laborious, or travel in the areas where fast charging infrastructure is not dense enough. Fast charging stations are still lacking in Northern and Eastern Finland, and therefore the long trips demand more planning and time in these areas. The current charging infrastructure is relatively difficult to use. There are several different charging provider companies that each require their own application and account. The charging infrastructure also lacks reliability; there have been problems with the functioning of the fast charging stations. Charging points must work properly in remote areas to increase the currently lacking trust towards electric vehicles. Because the number of electric vehicles is still small in Finland, it may not be profitable business to build the charging infrastructure on remote areas and therefore currently the charging infrastructure subsidies are needed (Ministry of Transport and Communications 2021). The current and future charging infrastructure's usability and reliability need to be ensured with cooperation between the government's charging infrastructure planning and charging infrastructure providers to reduce range anxiety.

Over a third of the respondents who did not choose an electric vehicle stated that CO_2 emissions from electric vehicle and battery manufacturing were the reason for not selecting an electric vehicle. This implies that more transparent research and information to the citizens on lifecycle emissions from battery electric vehicles is needed to enhance the acceptance of electric vehicles. For some respondents, an electric vehicle is not an option, regardless of its attributes. Approximately 13% of the respondents who chose a conventional vehicle in the choice tasks stated they do not want to drive an electric vehicle.

Non-participants state that they have read and heard about electric vehicles before this survey more often than the rest of the respondents. Compared to the rest of the respondents, they have searched less information on electric vehicles. These answers imply that the knowledge the non-participants have on electric vehicles may be hearsay and therefore not true. Future research is needed on the best ways to increase the knowledge of Finnish citizens regarding electric vehicles.

The non-participants drive on average more on a yearly level than other respondents. An electric vehicle, especially a battery electric vehicle, is a reasonable purchase for a person who drives a lot. Non-participants would benefit greatly from driving an electric vehicle since the more one drives, the more one saves on the operating costs. Real life experience on electric vehicle driving has proven to increase the acceptance of electric vehicles (Bühler et al. 2014, Jensen et al. 2013); thus, a way to reduce the negative attitudes towards electric vehicles and add understanding of the monetary benefits of driving an electric vehicle is to provide the citizens electric vehicle demonstrations and test drives.

Attitudes towards electric vehicles

The Finns have a broad scale of attitudes towards electric vehicles and approach road traffic emission reductions from different angles. Positively, one angle is acceptance towards electrification of the vehicle fleet and belief that electric vehicles reduce emissions from road traffic. Another viewpoint is general sustainability and the worry of environmental and societal effects of battery manufacturing. One point of view is the thought of biodiesel and biogas as great ways to reduce emissions from road traffic. Many respondents believe that a biodiesel price discount would be the best solution to emission reductions from road traffic. In addition, a negative attitude towards electric vehicles and disregard for climate change is showing among the respondents. However, the majority of the respondents do not have a specific point of view on this topic; rather, they have a viewpoint that combines these. This grouping gives insight into the Finnish worldview and can be utilized when designing policy instruments or, for example, when planning to increase the knowledge about electric vehicles. Conducting this survey questionnaire again after a few years would reveal if the growing knowledge of electric vehicles and increasing charging infrastructure affect the attitudes and perceptions on electric vehicles.

The respondents found some of the attitudinal statements challenging to answer or state their opinion on, indicating that these topics may be new to them or the subject does not affect their daily lives. These subjects are related to converting a conventional vehicle rather than purchasing a new electric vehicle, electric vehicle emissions, the emission reductions from cheaper biodiesel, and directing biodiesel to heavy and air traffic. Finnish citizens might need a reminder that while biodiesel is one option to decrease emissions, the use of it needs to be directed to heavy and air traffic rather than private passenger vehicles.

Since the respondents seem to be unfamiliar with the electric vehicle issues, the actual meanings of different vehicle names may also have been unclear in the survey questionnaire. The difference between the words ‘electric vehicle’ and ‘battery electric vehicle’ could have been made even more explicit in the attitudinal statements. Some of the respondents may have mixed the words and assumed that electric vehicles mean only battery electric vehicles. The statement ‘Electric vehicle’s battery is not energy efficient enough’ has probably been misinterpreted since more than half agreed or strongly agreed with the statement.

6 Conclusion

The electric vehicle purchase price and fast charging time need to be reduced, and the driving range increased to enhance electric vehicle adoption. Before the electric vehicle purchase price decreases to conventional vehicle’s level, a higher purchase subsidy is required. Technological development reduces the charging time and extends the driving range rapidly. However, to tackle the issues citizens have regarding electric vehicles, the home charging infrastructure needs to be increased, and the fast charging infrastructure needs to be expanded in Northern and Eastern Finland in order to reduce range anxiety.

A necessary aspect of emission reductions is the increasing number of battery electric vehicles. Because the battery electric vehicle fleet is growing slower than the plug-in hybrid vehicle fleet and a plug-in hybrid is chosen more frequently than a battery electric vehicle, the focus should be on promoting battery electric vehicles. By increasing the share of battery electric vehicles, Finland has a higher likelihood of achieving its carbon neutrality target. Further research is needed on the tools that incentivize people who are willing to adopt a plug-in hybrid vehicle to switch to a battery electric vehicle purchase. As female gender, younger age, university degree, and living county Uusimaa positively affect the purchase of battery electric vehicles, it could be beneficial to take this group into consideration when planning the policy instruments. In addition, by incentivizing those who are known to buy new vehicles, i.e., 50+ males to choose a battery electric vehicle, the amount of pre-owned electric vehicles in the car markets could rise faster.

To support electric vehicle adoption, Finnish people need more information and experience on electric vehicle driving ranges and energy efficiency. In addition, Finnish drivers need to learn about their actual driving needs to understand that electric vehicle driving range is not necessarily an issue for them. More information about the fact that switching to an electric car is most profitable for those who drive the most due to low operational costs is needed.

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Appendices

Appendix 1. Survey questionnaire

At the University of Helsinki, we study the factors related to Finnish transportation. The purpose of the survey questionnaire is to determine your views on the vehicle fleet and plans for a future car purchase.

1. How many vehicles does your household have?
   0
   1
   2
   3+

2. Who is responsible for the vehicle purchase in your household?
   Me alone
   My partner alone
   Both of us together
   I don't know

3. [if two or more vehicles in the household]
   How many kilometres were driven during the last 12 months? [All cars]
   Car 1
   Car 2
   …

   When answering the rest of the questions, answer regarding the vehicle you use the most.

4. Where did you purchase the vehicle?
   New vehicle from a dealership
   Leasing vehicle from a dealership
   Used vehicle from a dealership
   Used vehicle from a elsewhere
   Other
   I don't know

5. How long have you owned the vehicle?

6. Which fuel does the vehicle use?
   Gasoline
   Diesel
   Electricity with gasoline (plug-in hybrid)
   Electricity with diesel (plug-in hybrid)

Electricity with gasoline (non-rechargeable hybrid)
Electricity with diesel (non-rechargeable hybrid)
Electricity
Gas
Other, what?

7. Vehicle brand

8. Vehicle model

9. Model year

10. How many days per week the car is in use? Combined for the household.
6-7
4-5
2-3
1
Varies
I don’t know

11. In which kind of environment do you drive the most?
Extra-urban
Urban
Same amount of both
I don’t know

12. How many kilometres do you drive the vehicle during a typical day?
<20 km
20-49 km
50-99 km
100-199 km
>200 km
I don’t drive regularly
I don’t know

13. Over the last year, what was the longest trip you took by car?
Please enter your best estimate as a whole number, in kilometres. Include rest stops, but no overnight stays.

14. [If only one vehicle in the household]
How many kilometres were driven with the vehicle over past year?

15. Estimate the vehicle’s fuel consumption
    l/ 100 km

16. Estimate the vehicle’s electricity consumption
    kWh/ 100 km

17. Estimate the vehicle’s CO_2 emissions from driving
    g/ km

FUTURE VEHICLE PURCHASE

18. When are you going to purchase your next vehicle?
    < 1 year
    1-2 years
    3-5 years
    >5 years
    I am not going to
    I don’t know

According to Statistics Finland, Finnish citizens have about two million passenger cars. Of these, 25 000 are electric vehicles, of which 21 000 are plug-in hybrid vehicles and 4 000 are battery electric vehicles. Battery electric vehicles run on electricity only. Plug-in hybrid vehicles have a rechargeable electric battery and a combustion engine. (Note that a plug-in hybrid does not mean a hybrid that can be charged by driving with a combustion engine)

19. How familiar are you with electric vehicles (battery electric vehicles and plug-in hybrid vehicles)? Choose all that apply
    I heard about electric vehicles for the first time from this survey
    I have read or heard about electric vehicles
    I have searched for information about electric vehicles
    I know someone who owns an electric vehicle
    I have considered buying an electric vehicle
    I have driven an electric vehicle

Electric vehicles can be charged at home, at certain gas stations, or public charging points. There are approximately 2 400 public charging points. This means roughly one charging point for every ten electric cars. There are fast charging points from Ekenäs to Muonio and from Rauma to Joensuu. Roughly, half of the public charging points are located in the Helsinki Metropolitan Area and the Turku and Tampere areas. The number of charging points will increase with the increase of the electric vehicle fleet.

20. Is it possible to charge an electric vehicle at your home?
    Yes
    No
    I don't know

21. Is it possible to charge an electric vehicle at your working place?
    Yes
    No
    I don't know

According to Statistics Finland, passenger vehicles account for about 10% of total emissions in Finland. CO_2 emissions from passenger vehicles will decrease as the proportion of electric vehicles increases.

The following questions describe possible car purchase situations in the coming years. You can compare three alternative cars - a battery electric vehicle, a plug-in hybrid, and a conventional vehicle - and their potential features. Vehicle features are:

[middle size]

- **CO_2 emissions from driving** per kilometre (CO_2-eq)
    - BEV: 0 g / km
    - PHEV: 38-58 g / km
    - CV: 142 - 162 g / km
- **Driving range** is the distance you can drive with a full battery and/or fuel tank. The range depends on the size of the battery and the vehicle's consumption. Electricity can be charged every 50 to 100 kilometres in highways.
    - BEV: 200 – 500 km
    - PHEV: 500 - 680 km
    - CV: 500 - 800 km
- **Fast charging duration** is the time that it takes to recharge electric battery from 0 to 80 %. (Home charging BEV 4-10 hours, PHEV 1-4 hours)
    - BEV and PHEV: 10 – 60 min
- **Driving cost** depends on cars consumption, and fuel and electricity prices
    - BEV: 16 - 26 € / 1000 km
    - PHEV: 26 - 36 € / 1000 km
    - CV: 78 - 118 € / 1000 km
- **Purchase price**
    - 17 000 – 41 000 €

[Six random choice tasks for every respondent]

1. Choose one of the options A, B, and C.

	A	B	C
	Battery electric vehicle	Plug-in hybrid vehicle	Conventional vehicle
CO_2-emissions	0 g/km	48 g/km	162 g/km
Driving range	500 km	500 km	650 km
Fast charging time	10 min	30 min	
Driving cost	26 €/ 1000 km	36 €/ 1000 km	78 €/ 1000 km
Purchase price	41 000 €	24 000 €	17 000 €

2. Compare the chosen vehicle to your current vehicle. Which would you choose?

[If a combustion engine vehicle was chosen in any of the choice situations]

22. Which were the reasons you did not choose an electric vehicle?
    Electric vehicle driving range is too short for my needs
    The charging of electric vehicle is too laborious
    I think CO_2 emissions from electric vehicles and their battery manufacturing are too high
    I don't think there will be enough charging points
    The purchase price of electric vehicles are too high
    I don't want to drive an electric vehicle
    Other
    I don't know

23. How much do you agree or disagree with following statements
    [strongly agree, agree, neither agree nor disagree, disagree, strongly disagree, I don't know, I don't want to answer]
    - Electric vehicles are an efficient way to improve air quality
    - I like to test new technology
    - I need a combustion engine vehicle for long-distance travelling
    - I would purchase an electric vehicle if I could charge it at home or work
    - An electric vehicle fits my daily driving routine
    - Electric vehicles can reduce CO_2 emissions from road traffic
    - It is safe to drive an electric vehicle
    - Electric vehicle's battery is not energy efficient enough
    - Electric vehicle production chain should be more transparent

    - An electric vehicle has a higher status than a combustion engine vehicle
    - Reducing emissions from air traffic is more important than from road traffic
    - The share of passenger vehicle traffic in Finland's total emissions is small, and therefore it is not worth investing in its emission reductions
    - It is more reasonable to wear out an old vehicle rather than buy a new electric vehicle

- I am concerned about battery material extraction's social and biodiversity effects
- The use of biodiesel should be directed to heavy and air traffic

- I try to reduce my carbon footprint
- Cheaper biodiesel would be the best solution to reduce emissions from passenger vehicle traffic
- My closest friends and family think that driving an electric vehicle is a good thing
- Global warming and its effects are exaggerated
- Biogas is an environmental fuel option
- Driving a battery electric vehicle does not reduce emissions because of its emissions from battery manufacturing
- It is convenient to rent a car for holidays
- It is more reasonable to convert a conventional vehicle to a bioethanol or gas vehicle rather than buy an electric vehicle
- Compared to other people, I am more willing to take risks

24. What do you want to say about the topic
    [open]

25. Risk aversion

[set 1]: Would you rather take a certain amount of money (A) or would you participate in a raffle (B) that determines the amount of money you get with a throw of a 10-sided die. Which would you choose A or B?

1 A) 35€
B) 78€ if the value of the die is 1
or 2€ if the value of the die is 2-10

2. A) 35€
B) 78€ if the value of the die is 1-2
Or 2€ if the value of the die is 3-10

3. A) 35 €
B) 78€ if the value of the die is 1-3
Or 2€ if the value of the die is 4-10

4. A) 35 €
B) 78€ if the value of the die is 1-4
Or 2€ if the value of the die is 5-10

5. A) 35 €
B) 78€ if the value of the die is 1-5
Or 2€ if the value of the die is 6-10

6. A)35 €
   B) 78€ if the value of the die is 1-6
   Or 2€ if the value of the die is 7-10

7. A) 35 €
   B) 78€ if the value of the die is 1-7
   Or 2€ if the value of the die is 8-10

8. A) 35 €
   B) 78€ if the value of the die is 1-8
   Or 2€ if the value of the die is 9-10

9. A) 35 €
   B) 78€ if the value of the die is 1-9
   Or 2€ if the value of the die is 10

10. A) 35 €
    B) 78€ if the value of the die is 1-10

[set 2]: Would you rather take a certain amount of money (A) or would you participate in a raffle (B) that determines the amount of money you get with a throw of a 10 sided die. Which would you choose A or B?

1. A) 35 €
   B) 40€ if the value of the die is 1-5
   Or 16€ if the value of the die is 6-10

2. A)35 €
   B) 44€ if the value of the die is 1-5
   Or 16€ if the value of the die is 6-10

3. A) 35 €
   B) 48€ if the value of the die is 1-5
   Or 16€ if the value of the die is 6-10

4. A) 35 €
   B) 52€ if the value of the die is 1-5
   Or 16€ if the value of the die is 6-10

5. A) 35 €
   B) 56€ if the value of the die is 1-5
   Or 16€ if the value of the die is 6-10

6. A) 35 €
   B) 60€ if the value of the die is on 1-5
   Or 16€ if the value of the die is 6-10

7. A) 35 €
   B) 64€ if the value of the die is -5
   Or 16€ if the value of the die is 6-10

8. A) 35 €
   B) 68€ if the value of the die is 1-5
   Or 16€ if the value of the die is 6-10

9. A) 35 €
   B) 72€ if the value of the die is 1-5
   Or 16€ if the value of the die is 6-10

10. A) 35 €
    B) 76€ if the value of the die is 1-5
    Or 16€ if the value of the die is 6-10

26. Which of the following describes best your residential area?
    Countryside
    Rural local centre
    Suburb
    Urban

Appendix 2. 'Other' reasons for not choosing an electric vehicle in the choice experiment

[If a combustion engine vehicle was chosen in any of the choice situations]
22. Which were the reasons you did not choose an electric vehicle?
Other:

- An electric vehicle cannot pull a trailer.
- Charging time is too long. There is not enough information about the responsibility of battery manufacturing and fire safety.
- Charging time is too long. It is an option only if it takes the same time as fuelling a conventional vehicle.
- The minerals needed for battery manufacturing are harmful to the environment in the areas where child labour is used.

- There is no charging possibility at my housing association at the moment,
- I would rather use biodiesel for my current vehicle.
- The transmission of electricity is costly.
- The re-sell value is a mystery.
- The faith of used batteries.
- Electric vehicles ruin the environment and are repulsive and useless.
- Only slow home charging is possible, I don’t want to wait in ‘fast’ charging stations.
- Electric vehicles are unreliable (in repair shops all the time).
- There are no electric vans available.
- The current situation is the best without change.
- Not enough charging points
- The survey has not considered taxes. That could affect the willingness to purchase. I will stay in my current vehicle because I cannot afford to purchase a new vehicle. In cold winter temperatures, I would be afraid to be dependent on an electric vehicle.
- Battery vehicle charging port stays open when the chord is in place outside in heavy rain and is predisposed to vandalism
- Charging time is too long
- Many hybrids and electric vehicles cannot pull a 1300 kg trailer. Those kinds of hybrids are too expensive for a pensioner.
- I don’t trust that electric vehicles work in the winter conditions in Finland. Too long charging time.
- It takes too long to charge.
- I only drive a little.
- Electric vehicles don’t work. If you need to drive a longer distance, the driving range is too short, charging time too long!
- Current vehicle needs to be worn out, without a credit score, you cannot purchase anything other than old conventional vehicles.
- My current vehicle consumes 5 l/ 100 km, and the driving range is 850 km. It is not ecological to change a newish working vehicle to another. If you are buying a new vehicle, it is a different situation.

Appendix 3. Characteristics of the non-participants

Socio-demographic characteristics of the non-participants, n=37

	%		%
Age		Residential area	
18-29 years	5.4	Uusimaa	32.5
30-49 years	27.0	Rest of Southern Finland	21.2
50-69 years	51.4	Western Finland	25.8
Over 70 years	16.2	Northern or Eastern Finland	20.4
Gender		Åland islands	0.0
Female	18.9	Living environment	
Male	81.1	Countryside	31.6
Education		Rural local centre	0.0
Basic education	18.9	Suburb	15.8
Vocational upper secondary education and training	24.3	City	51.6
General upper secondary education	2.7	I don't know	0.0
College level vocational undergraduate degree	24.3	House type	
Bachelor's degree	18.9	Block building	35.1
Master's degree or higher of university or college	8.1	Row or semi-detached house	10.8
Other	2.7	Detached house	48.6
Occupational group or situation		Detached house in a farm land	5.4
A leading position employed by another	2.7	Other	0.0
Senior officer	10.8	Living situation	
Junior officer	5.4	With parents	2.7
Employee	24.3	Alone	29.7
Entrepreneur or self-employed	8.1	Together with partner	37.8
A farmer	2.7	With partner and children	24.3
Unemployed	8.1	Single parent with children	2.7
In school or a student	0.0	Other	0.0
Pensioner	29.7	I don't want to say	2.7
Stay-at-home parent	2.7	Household size	
Other	2.7	1	29.7
I don't want to answer	2.7	2	37.8
Household's total annual net income		3	18.9
Less than 20 000 €	13.5	4	8.1
20 001 - 35 000 €	16.2	5	5.4
35 001 - 50 000 €	8.1	6 or more	0.0
50 001 - 85 000 €	18.9		
85 001 - 100 000 €	21.6		
Over 100 000 €	8.1		
No answer	10.8		
I don't know	2.7		

Current vehicle information and driving habits of the non-participants n=37

	%		%
Number of vehicles in household		Driving kilometres per day	
0	2.7	Less than 20	13.9
1	54.1	20-49	50.0
2	27.0	50-99	22.2
3 or more	16.2	100-199	11.1
Current vehicle		Over 200	2.8
Purchase		I don't know	0.0
New from dealership	19.4	Knowledge of vehicle’s consumption	
Leasing, New from dealership	2.8	Knows	97.3
Pre-owned from dealership	44.4	Does not know	2.8
Pre-owned from elsewhere	30.6	Knowledge of vehicle’s CO_2 emissions from driving	
How long have you owned the vehicle		Knows	54.1
Less than a year	19.4	Does not know	47.2
1	8.3	Who is responsible for vehicle purchase?	
2	5.6	The respondent alone	52.8
3	25	Respondents spouse alone	5.6
4	5.6	Both together	41.7
5	5.6	I don't know	0.0
6	5.6	Future vehicle purchase	
7	5.6	Less than a year	13.5
8	5.6	One to two years	18.9
9	2.8	Three to five years	29.7
10 or more	11.1	Over five years	8.1
I don't know	0.0	Not going to purchase a vehicle	0.0
Fuel		I don’t know	29.7
Gasoline	56.8	Electric vehicle charging possibility at home	
Diesel	37.8	Yes	21.6
Plug-in hybrid	0.0	No	67.6
Hybrid	0.0	I don't know	10.8
Gas	2.8	Electric vehicle charging possibility at work	
Flexfuel	0.0	Yes	5.4
Battery electric vehicle	0.0	No	81.1
Driving type		I don't know	13.5
Extra-urban	38.9	I heard about electric vehicles first time in this survey	0.0
Urban	19.4	I have heard or read about electric vehicles before	81.1
Both equally	41.7	I have searched information about electric vehicles	5.4
Don't know	0.0	My friend owns an electric vehicle	10.8
Vehicle in use, days per week		I have considered buying an electric vehicle	0.0
Six to seven	47.2	I have driven an electric vehicle	8.1
Four to five	33.3		
Two to three	16.7		mean
One	0.0	Kilometres driven in a year	18 649
Varies	2.8	Longest trip during last 12 months	540

Appendix 4. Non-participants responses to the attitudinal statements